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Chapter 2—Vernacular and contemporary buildings in Qatar

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1. Introduction

"The strength of vernacular architecture is that it blends buildings into various settings so that there is a natural harmony between climate, architecture and people. In countries such as Iran, Iraq and Egypt there have evolved buildings which not only demonstrate this harmony and unity between people and their environment but also offer a combination of engineering and architecture which has an aesthetic quality" [1].

In the past, people in Qatar built their houses according to their real needs and in harmony with the environment as well as with optimal utilization of the available local building materials. In spite of the hot long summer with the dry bulb temperature of up to 45°C, human comfort was achieved in those traditional buildings by the utilization of natural energies. This was the result of repeated cycles of trial and error and the experience of generations of builders. It is worth mentioning that builders had to rely mostly on the locally available material to construct the buildings with the exception of timber which was imported from India.

In the 1940s the country's economy flourished as a result of oil discovery, and electricity was introduced. Modern technologies were adopted without studying their suitability with regard to culture and climate. An architectural heritage that survived for centuries because of geometric, technical and constructive principles that work for the society, is being sadly destroyed under the guise of modernization. Traditional buildings are being abandoned as it is perceived that they reflect underdevelopment and poverty.

This chapter is devoted to discussing various passive techniques that has been employed in the traditional buildings and their role in providing comfort especially during the hottest hours of the day.

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2. Vernacular architecture

2.1. *Passive techniques employed in traditional Qatari buildings*

Vernacular buildings in Qatar have employed some ingenious passive techniques in order to restore thermal comfort within the building particularly during the hottest hour of the day. Such techniques are discussed hereafter.

2.1.1. *Town layout*

The buildings were joined close to each other. The houses, on the other hand, shared walls and this minimized the surface exposed to the sun. The streets were like a trench. This helped the buildings to shade one another as well as to shade the streets. The only spaces that received a great amount of sunshine were the open spaces such as the courtyards. At midday the courtyard received more solar radiation than the shaded areas. As these heated up, hotter air rose and denser, cool air rushed in automatically. The cool air was drawn from the shaded streets. The streets oriented in the direction of the prevailing wind which created a low pressure area in the open space thus moving the air from the streets into the living spaces.

2.1.2. *Massive walls*

The walls of traditional buildings were massive with a thickness of about 60 cm (Fig. 1). Various materials were used to construct the walls [2]. Such materials include:

(i) Mud: This was the only material with sufficient cohesion to form walls. It was stable in dry conditions, and was mixed with straw and sometimes wool to achieve maximum strength.
(ii) Coral stone: Coral stones were mixed with mud to form stronger and more durable walls. However, stone collecting was labor-intensive and time-consuming.
(iii) The coral slab ('Frush'): this material underlies the coastal waters; in some places it lies exposed, and in others is covered by several meters of sand or silt. It was mainly used to construct the *Badgir*, (refer to Section 2.1.4.).
(iv) Gypsum ('Jus'): gypsum was used to plaster the internal walls and only some of the external walls. A thin layer was also used on the rooftop to act as a reflector.
(v) Lime ('Nurah'): lime was used mainly to pigment the interior of a house with brilliant white. It could also be mixed with indigo to produce a light bluish colour.
(vi) Timber: dressed timber was used for doors and windows. The windows were unglazed, but were provided with wooden shutters on the outside to ensure privacy and to keep out dust, sun and rain (Fig. 2). Round timber poles ('danjal'), on the other hand, were used to form the framework of the roof and to support the wall above the windows. The *danjal* on the roof is covered with mangrove slats ('yereed') and a woven palm-frond matting ('mangrur'), and then by a mixture of mud and straw (or sometimes wool) (Fig. 3). Table 1 summarizes the properties of common building materials.

Fig. 1. A traditional massive wall.

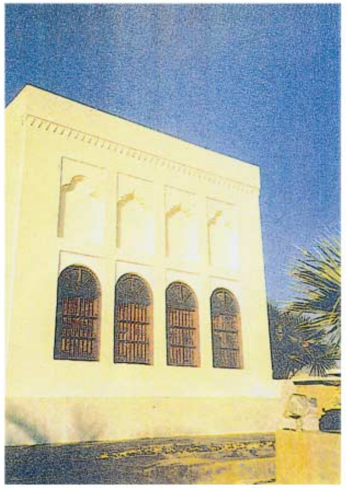


Fig. 2. A traditional window.

Fig. 3. A traditional roof construction.

Fig. 7. A traditional courtyard.

Fig. 9. Traditional wall air vents.

Fig. 10. A traditional wind tower.

Fig. 11. A modern building with a large area of glazing

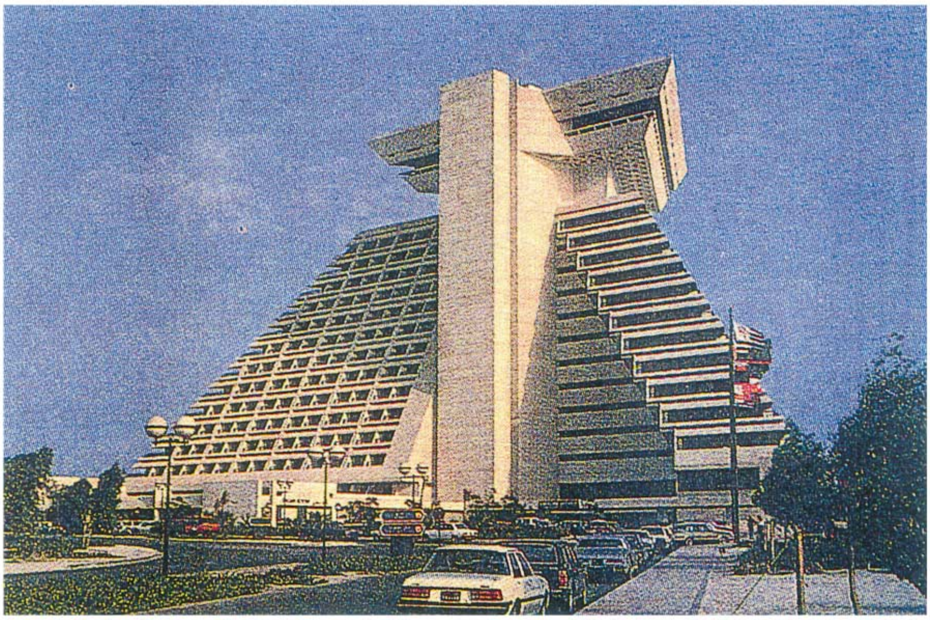


Fig. 12. Sheraton Hotel, Doha—energy wasteful building.

Fig. 13. Qatar University.

Fig. 14. The traditional coffee house of Qatar.

Table 1
Comparison of thermal and physical properties of commonly used materials

Material	Thermal Conductivity (W/m°C)	Specific heat (kJ/kg°C)	Density (kg/m3)	Thermal storage (kJ/m^3.°C)
Adobe	0.516	1.00	1730	1.73
Stone	1.8	0.92	2451	2.26
Reinforced concrete	1.728	0.96	2400	2.3
Hollow clay block	0.36	0.84	1029	0.86
Hollow cement block	0.6	0.84	1403	1.18
Solid cement block	0.789	0.84	1600	1.34
Thermal insulation mat.	0.0276	0.66	32	0.02

Buildings with high mass structure utilize their thermal storage capabilities to achieve cooling in different ways [3]:

(i) Damping out interior daily temperature swings
(ii) Delaying daily temperature extremes
(iii) Ventilating ‘flushing’ the building at night.

Furthermore, the thick walls, in addition to their insulating properties, act as a heat reservoir. During the hot day, the heat flow from exterior (due to solar radiation) to the inside is retarded and during cooler hours a part of the stored heat in the walls is released to the interior. This results in a minimization of temperature change inside the building (Fig. 4). On the other hand, in winter, heating requirements are reduced due to the heat stored in the walls and which is radiated during the night. In hot climates with large temperature swing (arid regions) daytime temperature is often so high that ventilative cooling is ineffective. On the other hand, the night air becomes low in contact with the thermal mass. Furthermore, night flushing is most effective in buildings occupied during the day, allowing the mass to be more effectively cooled.

Fathy, [4], conducted tests on experimental buildings located at Cairo Building Research Centre, using different materials. The materials used were mud brick walls

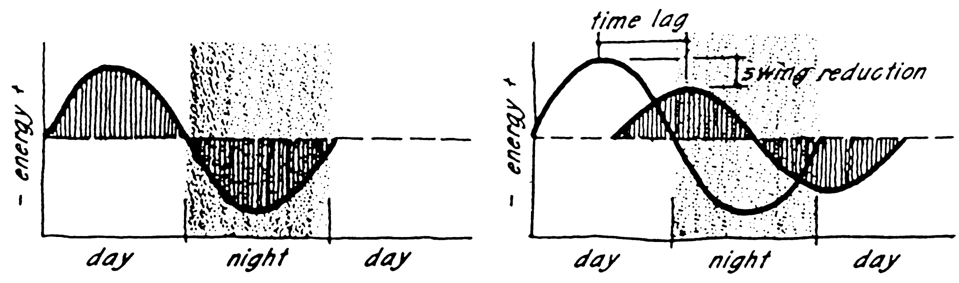


Fig. 4. Effect of thermal mass on interior temperature (Moore, 1993).

and roof 50 cm thick and prefabricated concrete panel walls and roof 10 cm thickness. Figure 5 shows the performance of the two buildings over a 24 h cycle. The air temperature fluctuation inside the mud brick model did not exceed 2°C during the 24 h period, varying from 21–23°C which is within the comfort zone. On the other hand, the maximum air temperature inside the prefabricated model reached 36°C, or 13°C higher than the mud brick model and 9°C higher than outdoor air temperature. The indoor temperature of the prefabricated concrete room is higher than the thermal comfort level most of the day. Moore (1993) reported the temperatures in and around an adobe building (Fig. 6). It indicates that when the average inside and outside temperatures are about equal, the maximum interior temperature occurred at about 22.00 h (about 8 h after the outside peak). Furthermore, the outside temperature swing was about 24°C while the interior swing was about 6°C. The shaded area represents the effect of night ventilation.

2.1.3. *Courtyards*

The traditional courtyard was surrounded by high narrow rooms having large unglazed windows facing the courtyard (Fig. 7). They were completely opened to the clear sky or partially shaded with overhangs and arcades. They tend to differ in size and shape according to the geographical location and type of climate. For example, in hot-humid regions, large courtyards provide good ventilation, especially when opening on to another courtyard or street such that cross ventilation is promoted. On the other hand, small courtyards provide more protection against hot, dusty winds in hot-arid regions. Some courtyards contain fountains and trees to promote evaporative cooling and provide shade. Courtyards moderate the climatic extremes in many ways:

(i) The cool air of the summer night is kept undisturbed for many hours from hot and dusty wind provided that the surrounding walls are tall and the yard is wide.
(ii) The rooms draw daylight and cool air from the courtyard.

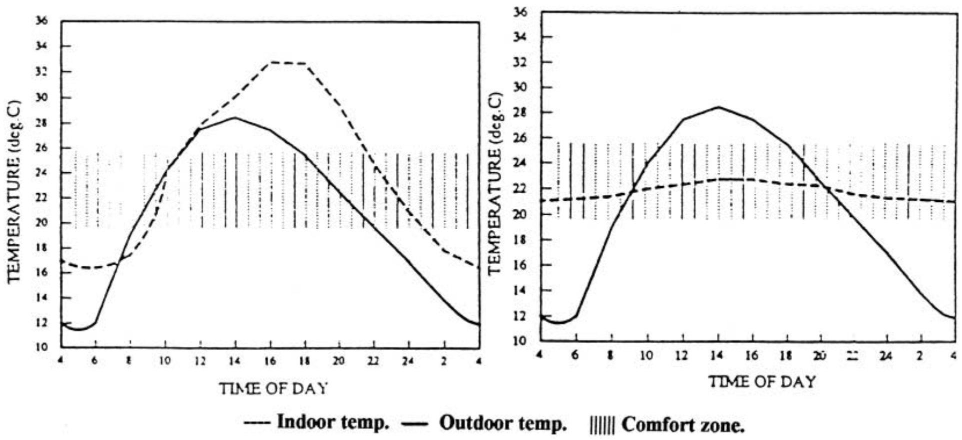
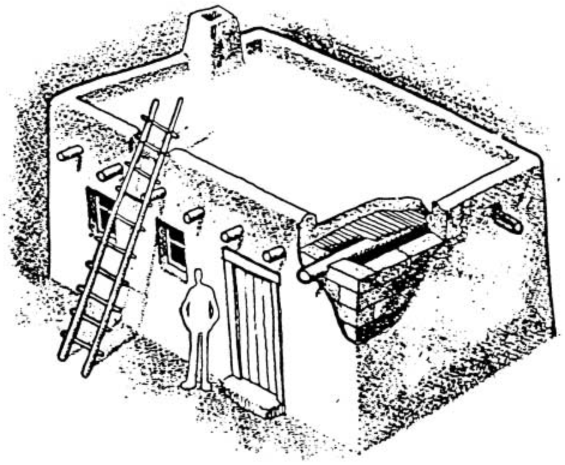


Fig. 5. Comparison of indoor and outdoor air temperature fluctuation within 24 h period (a) for the pre fabricated concrete test model; (b) for the mud-brick test model (Fathy, 1986).



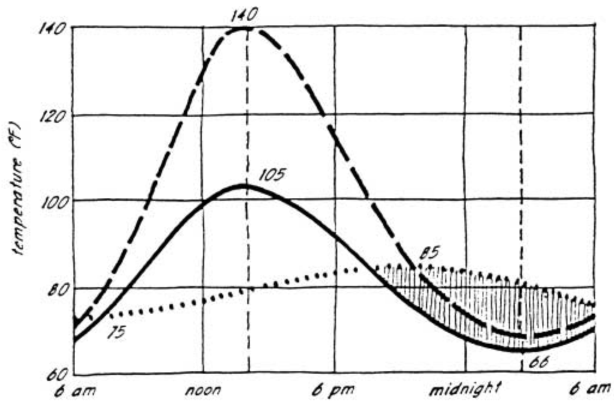


Fig. 6. Temperature in and around an adobe house (Moore, 1993).

(iii) It enhances ventilation and filter dust.
(vi) It provides privacy to the family and keep their activities and noise away from neighbours.
(v) The courtyard with its gentle microclimate provides a comfortable outdoor space to enjoy.

Talib [5], described the functioning of the courtyard during the 24 h cycle (Fig. 8). He subdivided the functions into three phases. In the first phase, cool night air descends into the courtyard and into surrounding rooms. The structure, as well as the furniture, are cooled and remain so until late afternoon. In addition the courtyard loses heat rapidly by radiation to the clear night sky. Therefore, the courtyard is often used for sleeping during summer nights. During the second phase, at midday, the sun strokes

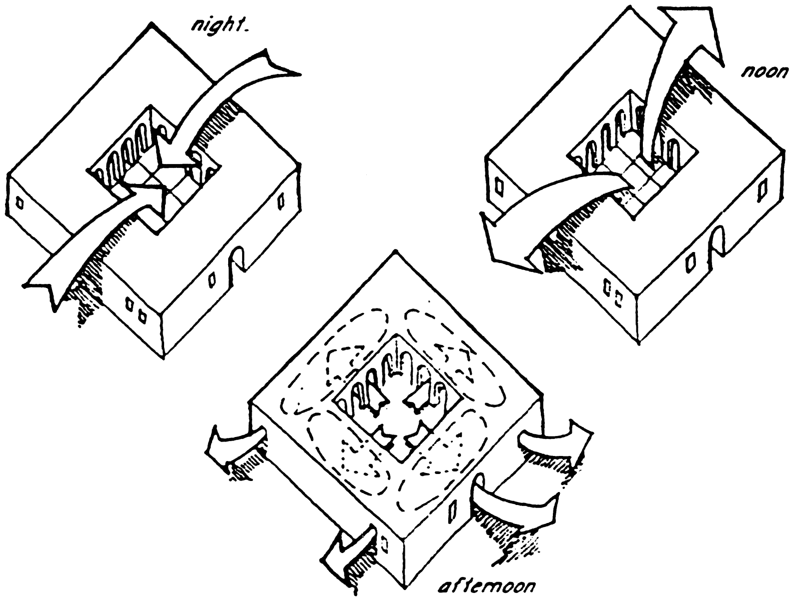


Fig. 8. The function of the courtyard during the 24 h cycle (Talib, 1984).

the courtyard floor directly. Some of the cool air begins to rise and also leaks out of the surrounding rooms. This induces convective currents which may provide further comfort. At this phase the courtyard acts as a chimney and the outside air is at its peak temperature. The massive walls do not allow the external heat to penetrate immediately. The penetration is delayed and depends on the time lag of the walls (up to 12 h). During the last phase, by late afternoon, the courtyard floor and the interior rooms become warmer. Most of the trapped cool air spills out by sunset. After sunset the air temperature falls rapidly (arid regions) as the courtyard begins to radiate rapidly to the clear night sky. Cool night air begins to descend into the courtyard, completing the cycle. It is worth mentioning that the courtyard concept is most effective in arid regions where a large diurnal temperature variation exists.

2.1.4. *Wall air vents*

This is a complex method of catching the breeze. The air vents are provided in the outer walls of the house (Fig. 9). Between the bearing columns of the house, twin panels of thin coral slabs are set parallel to each other in the wall. A space was left between the slabs, through which the air flows. The outer slab was a little short at the top and the inner slab a little short at the bottom. Thus the breeze enters through the gap at the top of the outer slab, and filters through the gap at the bottom of the inner slab into the room.

2.1.5. *The wind tower* (*'Badgir'*)

The traditional wind tower construction in Qatar is shown in Fig. 10. It consists mainly of two parts, the catching device and the tower. It is opened into either upstairs

or downstairs rooms and stopped about two meters above floor level. The tower is subdivided by brick partitions to contain several shafts.The wind tower in Qatar is built to an X-shaped design, open on the four sides to catch the breeze from any direction. The operation of the wind tower depends on wind conditions and the time of the day.

2.1.5.1. *Night operation*. When there is no wind blowing at night, the wind tower acts as a chimney. The tower walls which have been heated during the day transfer heat to the cool night ambient air. The heated air is then exhausted through the tower openings. The chimney action of the tower maintains a circulation of ambient air through the building and cools the structure of the building including the tower itself. When there is wind blowing at night, the air circulation will be opposite to that described above and the walls and rooms will be cooled.

2.1.5.2. *Day operation*. When there is no wind blowing during the day, the tower operates as the reverse of a chimney. The hot outside air in contact with the cold walls of the tower (cooled from previous night) is cooled and pulled down through the towers passages. When there is wind blowing, both the air circulation and the rate of cooling are increased, and thus, cooler air is delivered to further position inside the building. the performance of the wind tower is affected, beside its geometrical forms (height, cross sectional plan, tower orientation and location of its outlets), by the climatic conditions. It is most effective in dry arid regions. In such regions the diurnal variation is large and night air temperature is low.

3. Contemporary buildings in Qatar

Contemporary buildings in Qatar are generally built under the combined influence of British and American architecture. Since the generated electricity is subsidized by the government, it was provided to the private sectors at low rates (1 p/kW.h) whereas Qatari nationals receive electricity free. Therefore, the energy consumption each building required was not considered as a design criterion. A major design consideration was the visual impact of the building. Buildings were constructed of materials that are not suitable for the region's environment (steel and concrete). Dwellings constructed as a large enclosed glazed space with no provision for ventilation and protection from the sun (Fig. 11). High rise buildings have a high electricity consumption, as shown in Table 2 [6]. The Doha Sheraton (Fig. 12), for

Table 2
Air conditioning load in some hotels in Qatar (Sayigh, 1985).

Hotel	No. of rooms	Tonnage	Ton/Room
Sheraton	456	3750	8.3
Gulf Hotel	366	1300	3.6
Ramada Inn	302	1080	3.4

example, designed by a Japanese company and is constructed of steel frame. It has 16 storeys arranged in a pyramid shape. The side walls to the outside are totally made of glass panels. The hotel has 456 guest rooms and several meeting halls. It has a hollow pyramid shape with its fresh air intake at the bottom on the side of the prevailing wind. The air exhausts from the top which makes the air conditioning load very high. In summer, the hotel consumes 3750 tons of air conditioning.

In recent years, there has been an increased influence of the traditional architecture in modern buildings. Traditional concepts were adopted for its architectural form and not from an energy stand point. Nevertheless, this has resulted in lowering the cooling load for these buildings.

3.1. *Qatar University*

Dr Kamal Kafrawi, an Egyptian architect, has succeeded, to a great extent, in reconciling modern technology with the traditional elements of Arabic Islamic architecture (Mimar, 1985). Some of the elements utilized by the architect were (1) wind tower (2) protected courtyards (3) Moshrabiya (4) geometric forms (Fig. 13). The use of these elements has helped to control the harsh climatic conditions. The wind tower structures, which are one of the most outstanding features of the university, also provide the cover of the university buildings. The courtyards. both open and partially covered, provide connection and circulation spaces within the university complex. With their gardens and fountains, the courtyards provide pleasant areas of coolness and shade. The octagonal shape of the modular unit was derived from the traditional principles which enhances ventilation through wind towers and provide lighting through indirect sunlight.

3.2. *The traditional coffee house*

The traditional coffee house, designed by architect Shahab Nassim, incorporate many traditional features which creates a pleasant atmosphere within the house (Fig. 14). It is constructed of heavy fired clay brick walls with domes and arches to reduce thermal gain. There are three wind towers situated on three corners of the building. The whole building is situated on the seashore with no walls facing the sea in order to get maximum benefit from the sea breeze. It also contains courtyards, covered verandahs to promote coolness and provide shade.

4. Conclusions

The vernacular building form, structure and materials were selected to suit the climatic conditions and achieve a cool and stimulating environment for people using the buildings. Traditional architecture often displays buildings with heavy facades, limited openings on the external elevation and they are well shaded. The basic form of the traditional building employs a combination of mass, shade and ventilation which let the building breathe in harmony with nature and permit the best range of

comfort condition for occupants inside. The enclosed courtyard with trees, plants and fountains which cool the air by evaporation, help to keep dust down, provide shade, visual and psychological relief. The roof of the building receives the highest proportion of solar radiation and is also the surface most exposed to the clear cold night sky. Hence, the light colour of the roof, in the traditional building, is used for its high reflectivity to solar radiation and high emittance in the atmospheric window.

On the other hand, contemporary architecture which has replaced the traditional buildings in Qatar has the influence of western architecture. However, this type of building forms and materials was found unsuitable for the harsh climates of desert regions. therefore, it is important for the architect to understand how to blend lessons from tradition with modern technology in building design.

References

[1] Croome D. Building Services Engineering— the Invisible Architecture. University of Reading: The Information Office, 1990.
[2] Al-Mohanadi MR. The Potential of Passive Thermal Building Design in the State of Qatar. Msc. Thesis, University of Reading, 1989.
[3] Moore F. Environmental Control Systems. Edited by McGraw-Hill, 1993.
[4] Fathy H. Natural Energy and Vernacular Architecture. The University of London: Chicago Press Ltd., 1986.
[5] Talib K. Shelter in Saudi Arabia. New York: St. Martin's Press, 1984.
[6] Sayigh AA. Passive and Active Buildings in the Gulf Area. Solar and Wind Technology, 1985; 3(4):233–40.